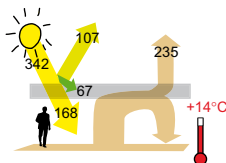
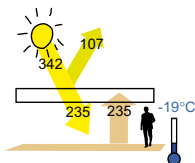


1.1 – The Greenhouse Effect

The Atmosphere's Role on the Greenhouse Effect

Energy flows, expressed in W/m^2 with or without greenhouse gases (GHG)



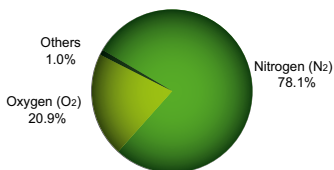
Source: after IPCC, 1st working group, 2007.

The sun supplies energy through its rays to the Earth which, in return, radiates an equal quantity of energy in the form of infrared radiation (IR). **In the absence of greenhouse gases (GHGs), the temperature of the Earth would be -19°C .**

With GHGs in the atmosphere, a portion of the IR is reflected back towards the surface of the Earth. The Earth's temperature increases until the energy radiated is equal to that absorbed. **The presence of GHGs leads to an increase in surface temperature, which then reaches $+14^\circ\text{C}$.**

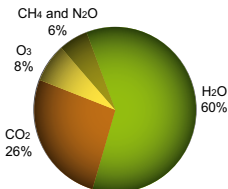
The Atmosphere and Greenhouse Gases

Composition of the dry atmosphere
(% of volume excluding H_2O)



Source: IPCC, 1st working group, 2001.

Share of the main greenhouse gases
in the reflection of radiation
towards the surface (in W/m^2)



Source: Kiehl & Trenberth 1996, National Center for Atmospheric Research.
N.B.: proportions in the absence of clouds.

GHGs other than water vapor make up **less than 0.1% of the atmosphere**. **Water vapor**, which fluctuates from 0,4% to 4% in volume, currently plays the largest role in the greenhouse effect.

The rise in the temperature of the Earth's atmosphere over the industrial era, corresponds to the **amplification of natural greenhouse phenomena by human activities**.

VISIT...

LANZAROTE
Caliente.COM

1.2 – Humans and the Greenhouse Effect

Characteristics of GHGs Influenced by Human Activity

	CO ₂	CH ₄	N ₂ O	HFC	PFC	SF ₆
Atmospheric Concentration 2005	379 ppm	1,174 ppb	319 ppb	60.6 ppt	76.9 ppt	5.6 ppt
Lifespan in the Atmosphere	Between 2 years and thousand of years	12 years	114 years	Between 1 and 260 years	About 10,000 years	3,200 years
Global Warming Potential (total over 100 years)	1	25	298	Between 124 and 14,800	Between 7,300 and 12,200	22,800
Sources in Human Activity	Burning of fossil fuels and tropical deforestation	Landfills, agriculture, livestock and industrial processes	Agriculture, industrial processes, use of fertilizer	Aerosols, refrigeration, aluminium smelting		
Change in Radiative Forcing Due to Anthropogenic Emissions since 1750 (W/m²)	+1.66	+0.48	+0.16	+0.337		

Notes: Ozone and water vapor omitted due to the complexity of their lifecycles.

ppm = part per million, ppb = part per billion, ppt = part per trillion

Source: IPCC, 1st working group, 2007.

The **Global Warming Potential (GWP)** of a gas is the ratio between the energy reflected towards the surface over 100 years per 1 kg of the gas and that which would be reflected by 1 kg of CO₂, used as a reference, over the same period. **The GWP depends on the concentration and lifespan of each gas.**

Ex.: 1 kg of CH₄ and 25 kg of CO₂, emitted at the same time, would heat the atmosphere equally over the century following their emissions.

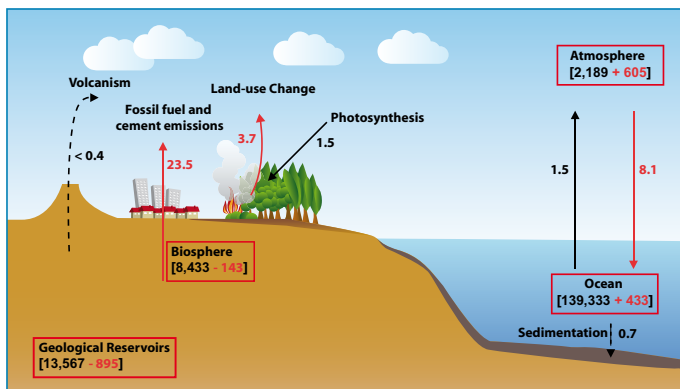
Radiative forcing quantifies, in relation to a year of reference (here 1750), the **changes in radiation**, or the energy reflected back towards the surface due to greenhouse gases. A positive value indicates a positive contribution to warming and vice versa.

Although **CO₂** has **the smallest global warming potential** of all greenhouse gases, it has nevertheless contributed **the most to global warming since 1750**.

Some human activities also contribute to reducing radiative forcing, most notably through the emissions of aerosols. However this negative radiative forcing, estimated at -1.20 W/m² since 1750, does not compensate for the positive radiative forcing of the six anthropogenic greenhouse gases which reached +2.64 W/m².

1.3 – Stocks and Flows of GHGs: The Example of CO₂

The Simplified CO₂ Cycle



This figure shows (i) as arrows, the carbon fluxes between reservoirs over the 1990-1999 period in billions of tonnes of CO₂ equivalent per year; (ii) between square brackets the size of the reservoirs in billions of tonnes of CO₂ equivalent and their variation over the 1750-2004 period. Pre-industrial reservoirs and flows are in black. Reservoirs' variations and flows induced by human activities since 1750 are in red.

Source: adapted from IPCC, 1st working group, 2007.

Four large reservoirs allow the storage of carbon in different forms:

- **Atmosphere:** gaseous CO₂
- **Biosphere:** organic material and living things
- **Ocean:** calcium, dissolved CO₂
- **Subsoil:** rocks, sediments, fossil fuels

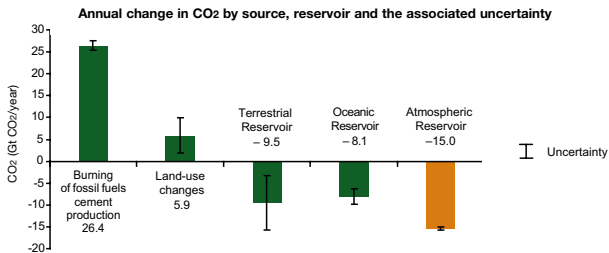
Flows of carbon between these reservoirs constitute the natural carbon cycle which is disrupted by human activities which change the size of the flows or create new ones.

E.g.: the burning of organic and fossil fuels (coal, petroleum...).

Of the **1,038 GtCO₂** liberated by human activities from the biosphere and the lithosphere, the atmosphere has absorbed **605 Gt** and the oceans **433 Gt**. The atmosphere is the reservoir which is the **most affected by human activities: the quantity of carbon absorbed has increased by 30% compared to the pre-industrial era.**

1.4 – Increase in Atmospheric GHG Levels

Imbalance between Emissions and Storage Capacity

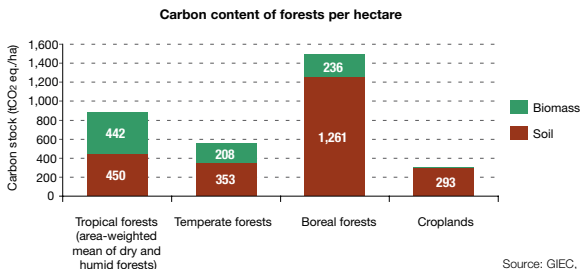


Emissions data from the burning of fossil fuels, the production of cement, the oceanic reservoir and the growth of the atmospheric reservoir are from the period 2000-2005. The terrestrial flows are for the 1990s. Emissions from the burning of fossil fuels and land-use change add up for half to the atmospheric reservoir and for about a quarter each the terrestrial and oceanic reservoirs.

Source: IPCC, 1st working group, 2007.

Since the increase in industrial activities, terrestrial and oceanic reservoirs have absorbed half of the human-related emissions. The atmosphere has therefore served to absorb the excess, which has led to **increased concentration of greenhouse gases**.

Importance of Forest Carbon



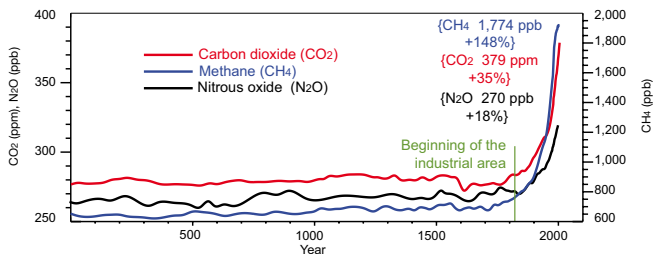
Source: GIEC, 2000.

Forests are the largest terrestrial carbon reservoir. They store approximately 9.5 Gt CO₂eq net emissions per year, equivalent to **30% of global GHG emissions**.

Deforestation leads to GHG emissions through **burning** and **decomposition** of organic matter, mainly in the form of CO₂. These gross emissions represent approximately 11% of yearly anthropogenic GHG emissions (Source: Van der Werf et al. 2009, Nature Geoscience).

1.5 – Concentrations and Temperatures

Historic Evolution of GHG Concentrations



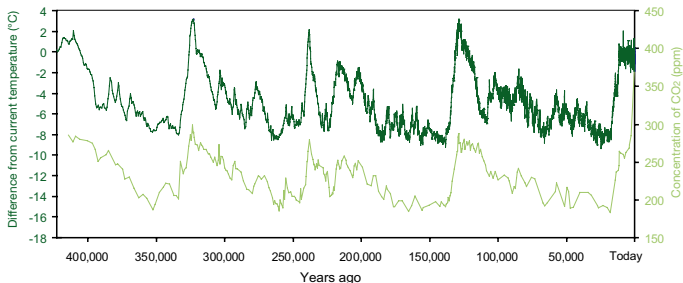
The figures in brackets indicate the atmospheric concentration of GHGs in 2005 and their percentage of growth between 1750 and 2005.

Source: IPCC, 1st working group, 2007.

The stable nature of concentrations before the industrial era shifted radically in 1750, exhibiting a strong increase in levels due to the intensification of human activities emitting large quantities of GHGs. **In 2008, atmospheric CO₂ concentration achieved 385 ppm**, 38% above pre-industrial level. (Source: World Meteorological Organisation, 2009).

Correlation between Temperature and CO₂ Concentration

Temperature and CO₂ concentration in the atmosphere over the last 400,000 years



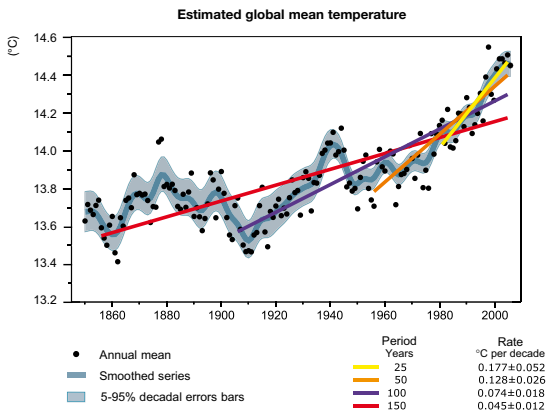
These results were obtained from the analysis of ice cores sampled at Vostok (Antarctica).

Source: World Data Center for Paleoclimatology, Boulder & NOAA Paleoclimatology Program.

The variations in temperature and CO₂ concentration are similar. If they are not fully understood, it is estimated that perturbing one of them leads to a perturbation of the other. The current **CO₂ concentration is 30% higher than the maximum observed over the 450,000 years of weather records.**

1.6 – Global Warming

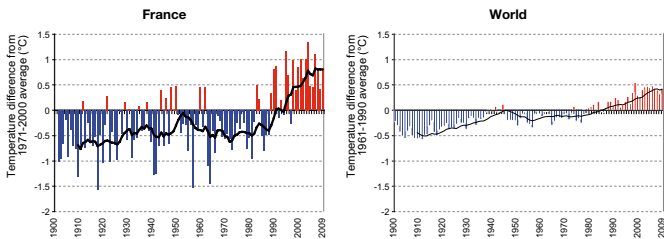
Estimated Global Temperature and Growth Rate since 1850



Source: IPCC, 1st working group, 2007.

The global average temperature has increased by approximately **+ 1 °C over the last century**. This **increase** is particularly apparent over **the last 25 years**, when the rate of temperature growth was **the strongest of the entire century**.

Mean temperature evolution in Metropolitan France and the world since 1901 compared with the reference period average



Source: Météo-France, 2010.

In France and in the world, **the temperatures of the last decade have systematically been above the average temperature of the reference period**. At the global scale, the last fifteen years (1995-2009) count fourteen of the fifteen warmest years since 1900.

1.7 – Warming Differentiated by Latitude

The expected increase in temperature varies according to latitude. The warming will be less in the tropics than at the poles. Equally, the increase in temperature in coastal regions is less than in inland.

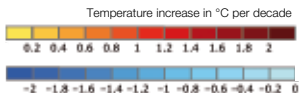
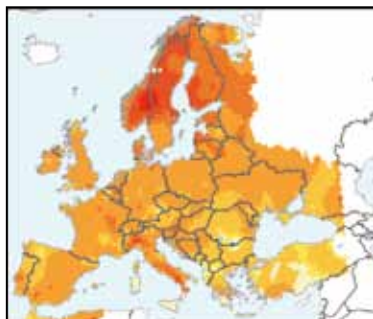
With reasonable hypothetical conditions (continued levels of observed economic and demographic development and balance between fossil and renewable energy sources), the **increases in annual temperatures over a single century** (period from 1999-2099) are estimated:

+ 3,5°C in Southern Europe	} For a global increase of + 2,8°C compared to the 1980-1999 period.
+ 2,5°C in Southeast Asia	
+ 4,9°C in the Arctic (North Pole)	
+ 3,2°C in Central America	
+ 2,6°C in Southern Australia	
+ 3,3°C In West Africa	

The regional temperatures' evolution is the median of all models' predictions under the A1B scenario of the IPCC. The increase in global temperature is the mean of the models' predictions under the same scenario.

Source: IPCC, 1st working group, 2007.

Observed temperature change in Europe 1976-2006



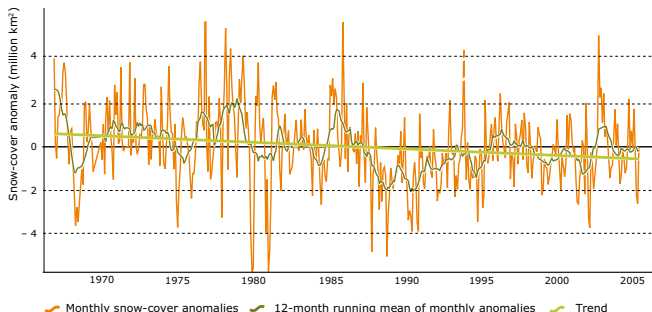
Source: European Environment Agency, 2008, from data of EU-FP6 ENSEMBLES Project and EC A&D Project.

There has been an increase in mean temperatures in Europe during the period 1976-2006. This evolution is not uniform: **the increase is greater in the North.**

1.8 – Consequences of Global Warming

Decrease in Snow Cover

Northern hemisphere snow cover extent variation 1966-2005

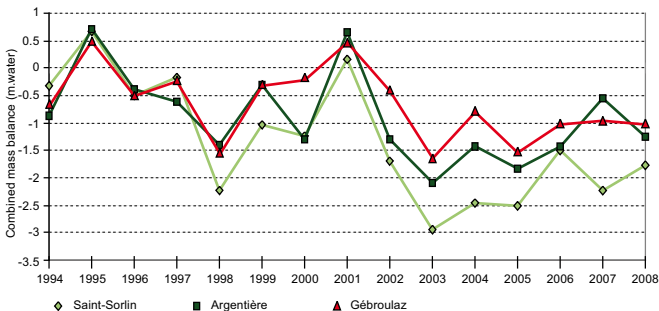


Snow-cover anomaly refers to the difference between each monthly value and the annual mean.

Source: European Environment Agency, 2008.

Melting Ice

Combined mass balance evolution of 3 glaciers from French Alps since 1994



Source: Laboratoire de Glaciologie et de Géophysique de l'Environnement (LGGE), 2010.

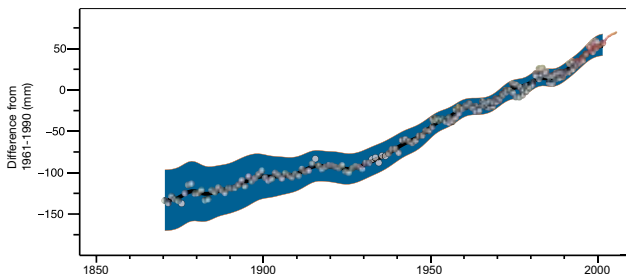
The run down of glacier mass from the Alps has not been uniform over the period. The **falls in levels** (as a result of winter with a small amount of snow and very hot summer) have been punctuated with **short phases of growth**.

1.8 – Consequences of Global Warming

Increase in Sea Level Worldwide

Global warming affects sea levels worldwide. Readings indicate a **continued increase** in levels since the 1870s.

Global average sea level



Source: IPCC, 1st working group, 2007.

Increases in sea level will most likely lead to **migration of population** living in flooded areas or who have no access to drinking water because of the salinization of essential groundwater resources.

The Various Causes of Increased Sea Level

Increase in sea level (mm/year) and contribution to measured growth				
Causes	1961-2003		1993-2003	
<i>Thermal Expansion</i>	0.42 ± 0.12	23%	1.6 ± 0.05	52%
<i>Melting of Glaciers and Polar Ice Caps</i>	0.50 ± 0.18	28%	0.77 ± 0.22	25%
<i>Melting of Glacial Cover of Greenland</i>	0.05 ± 0.12	3%	0.21 ± 0.07	7%
<i>Melting of Glacial Cover of Antarctica</i>	0.14 ± 0.41	8%	0.21 ± 0.35	7%
Sum of Contributions	1.1 ± 0.5	61%	2.8 ± 0.7	90%
Increase Measured	1.8 ± 0.5	100%	3.1 ± 0.7	100%
Difference	0.7 ± 0.7	29%	0.3 ± 1.0	10%

Source: IPCC, 1st working group, 2007.

Over a decade, the principal factors of growth of global sea levels are **thermal expansion** and the **melting of terrestrial ice deposits** (glaciers, polar ice caps, snow cover, permafrost).

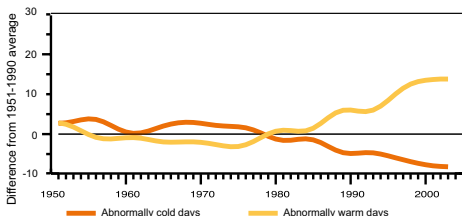
Extreme Weather Events

A weather event is classified as extreme when it substantially exceeds a **base of reference**. Extreme events are always unpredictable; it is **their increase in average frequency of occurrence or average intensity** that can indicate climate changes.

A number of weather events can be considered as extreme: tornadoes, hurricanes, as well as heat waves or abnormally heavy rainfall.

Temperature and Precipitation Extremes

Abnormally cold and warm days



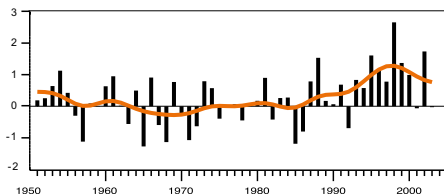
The reference used is the mean of the indicator considered over the period 1961-1990. The curves represent the mobile averages per decade. All regions worldwide are not included due to insufficient data.

Source: IPCC, 1st working group, 2007.

A day is considered abnormally cold (or warm) when the observed temperature is below (or above) the limit of 90% of the coldest (or hottest) temperatures recorded between 1951-1990.

A decrease in the number of days abnormally cold and a growth in the number of days abnormally warm have been **noted since the 1990s**. **Anomalies** in precipitations have also been noted over the same time period.

Anomalies in precipitations (%)



The indicator used is the portion of rainfall abnormally high in terms of yearly precipitation. This graphic presents the difference, in %, between this portion and the mean observed between 1961-1990. The orange curve shows the variations per decade. All regions worldwide were not included due to insufficient data.

Source: IPCC, 1st working group, 2007.